THE INFLUENCE OF SOIL TREATMENTS UPON THE CHEMICAL COMPOSITION OF LEGUMES AND LEGUME GRASS MIXTURES

by

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INTRODUCTION

These experiments were conducted in the field and in the laboratory to ascertain the effects of additions to the soil of various nutrient elements upon the yield and chemical composition of alfalfa, alfalfa-bromegrass mixture and red clover grown at Thayer, and alfalfa grown at Manhattan and Kingman.

According to Beeson;

> "Investigations designed to study the effect of the single factor, soils, on the composition of plants are rare indeed, which is unusual when one realizes for what length of time the importance of this one factor has been understood. Probably just a few field and greenhouse experiments may really be considered to have demonstrated that differences in soils alone are responsible for differences in such constituents as calcium and phosphorus in plants.
>
> Fertilizer experiments have, for the most part, been concerned with the study of yields, and in comparison, very few have included the problem of modifying the composition of the plant. That the composition of the plant is modified by the use of fertilizers has been known since the earliest soil fertility studies were made, and, in fact, plant composition has often been used as a guide for determining the nutrient requirements of the soil. One of the first and most comprehensive investigations of this nature ever undertaken is that of Lawes and Gilbert in 1884. They analyzed 92 wheat-grain and the same number of wheat-straw samples collected over a period of years. Every sample was from a crop of known history of growth, as to soil, season, and manuring. Nine different fertilizer treatments were investigated, and much valuable information was obtained concerning yields and crop quality." (6)

There were other early workers.

Out of the confusion of contradictory results of fertilizer experiments some definite conclusions may be made.

In these experiments a few of the principal plant nutrients in the soil were arbitrarily measured but no extensive studies of the effect of the soil amendments on the soil were measured.

Only the yield and chemical composition of the forages will be considered in this thesis.

REVIEW OF LITERATURE

Work similar to this reported in this thesis has been done at the New Jersey Agricultural Experiment Station by Bear and Wallace. (4) They combined field, greenhouse and laboratory studies to evaluate the several soil-plant relationships involved in successful production of alfalfa.

On the basis of their studies approximate critical levels for the content of several nutrient elements were established for alfalfa. They are: for K about 1.4 percent; for Mg., about 0.24 percent; for P, about 0.27 percent; for Mn., about 10 ppm; and for B, about 20 ppm.

Morrison (10) has shown that the composition of alfalfa and other forages depends upon the stage of maturity at which it is cut and how well it is handled when cut. The percentage of protein and the content of minerals and vitamins all decrease decidedly as hay crops advance in stage of growth.

Bear and Wallace (4) have shown that the equivalent sum of the K, Ca, Mg, and Na in alfalfa, for a particular cutting, tends to be a constant under uniform environmental conditions, except as to nutrient supply. An increase or decrease in one of these cations results in equivalent increases or decreases in the others. K tends to replace Ca and Mg.

Work was done by Wallace (19) to show that alfalfa, when grown in water and sand cultures ordinarily contains much higher

cation and anion values than does field grown alfalfa of the same maturity. This fact suggested that a nutrient concentration factor was at least partly responsible for the above observation.

The correlation coefficient of the sum of the exchangeable bases in the surface six inches of soil on which field-grown alfalfa samples were grown and of the cation milliequivalent sum of the alfalfa from these soils was +0.64 and highly significant. This means that there was a tendency for saturated soils having a high cation exchange capacity to produce alfalfa with a high cation content.

Bear and Prince (5) concluded from experimental evidence that the sum of the equivalents of Ca, Mg, and K per unit of plant material tended to be a constant for the produce of any given harvest, this constant having a value approaching 170 M.E. per 1.00 g. dry matter in the first crop.

The evidence supports the belief that each of these cations has at least two functions in the plant, one specific and the others of the type that can be performed interchangeably by all three cations.

The practical use of potash in crop production depends to a large extent upon the potassium requirement of the specific crop and the potassium supplying power of the soil. Alfalfa and Red Clover have a marked capacity to absorb much larger quantities of K than are necessary for maximum growth. This is objectionable because most of the available soil K may be removed in the first few cuttings after seeding. This difficulty can be overcome by supplying K in increments rather than in large

individual doses. (4)

Soil differences are extremely important in determining the fertilization of any crop. (3) Soils vary in their total potassium content, in the amount of readily available potassium, and in their ability to fix soluble potassium in unavailable forms.

Bauer (3) noticed that legumes are more responsive to potash than are grasses.

Through the use of colloidal clay as a growth medium, Albrecht (1) formulated concepts regarding potassium. One concept was that calcium promotes proteinaceous properties in plant material, while potassium promotes carbonaceous properties.

Applications of boron are very important in the production of alfalfa on soils that are deficient in B.

A careful quantitative study was made by Reeve and Shive (15) of the responses of tomato plants to different boron treatments when grown within relatively wide ranges of known levels of potassium and of calcium supplied to the plants in a basic nutrient solution in sand culture.

The potassium concentration of the nutrient substrate has a definite influence upon the accumulation of boron in the tissues of the tomato plant.

At any given boron level in the substrate, there is a progressive increase in the boron content of the plants as the K concentration of the substrate increases.

Inadequate supplies of K and B have even associated with short life and low yield of alfalfa in eastern U. S. For this reason, studies of these two elements on the behavior of this

plant were made by Wallace and Bear. (20)

Plants were grown in sand culture experiments using nutrient solutions. It was thought that an increase of B in the nutrient solution, at moderately low K levels, might lessen the K requirement by keeping Ca in solution and thus releasing K for other functions. This did not prove to be so.

Dry matter production of alfalfa in these experiments was increased up to 3 percent in the plant tops. It may not be practicable to maintain K at this level; a value midway between a suggested critical value of 1 percent and 3 percent being more logical for field production. Plants having very high K concentrations are low in Ca. This could impair their nutritive value as a forage.

A number of fertility plots in southeastern Kansas were placed on established stands of alfalfa in the spring of 1947, by Smith. (17) The treatments included the use of boron in combination with phosphorus and the use of phosphorus and potassium without boron, as well as no treatment plots and plots receiving phosphorus and potassium plus magnesium.

The application of PK treatments or PK + Mg treatments had very little influence on the content of boron in the plant tissue despite the fact that such treatments outyielded the no treatment plots.

Alfalfa and Red Clover are relatively high in phosphorus and usually show marked response to applications of this element.

Studies of 20 New Jersey soils (13) permitted their grouping according to phosphorus requirements for alfalfa. Large increases

in yield from applications of P were obtained on 14 of the 20 soils. The P content of the alfalfa grown on the 14 was materially increased by use of this element.

Myers (11) stated that phosphorus was the main fertilizer element needed by the alfalfa crop growing in Kansas soils. In addition lime was also needed for the production of alfalfa on acid soils. Superphosphate may be used successfully anywhere in Kansas where additional phosphorus is needed.

The principles underlying the successful use of fertilizers on red clover are essentially the same as for alfalfa.

High-K plants tend to be low in Ca and in protein. Calcium, however, is more important from an animal nutrition point of view.

It was found that if the Ca content of the alfalfa plant material became greater than 2 percent, an abrupt drop in yield resulted. This was accompanied by a reduction of the potassium content to below 1 percent with a calcium-potassium ratio in the soil of about 4:1.

Greenhouse experiments were conducted by Schmehl it. al. (16) to study the influence of soil acidity and its associated factors on the absorption of calcium by alfalfa. Radioactive calcium was used to label the $CaCO_3$ applied to the soil and the Ca supplied in nutrient solutions.

One significant conclusion was that the rate of absorption of calcium by alfalfa was markedly reduced in presence of Al^{+++}, and to a lesser degree, Mn^{++} and H^+ in nutrient solution.

Thus the low calcium content usually observed in plants grown on acid soils may be due to the antagonistic effect of these

elements.

It has been suggested that sodium may be beneficial to plants in one or all of the following ways: (9)

By replacing K in some of its functions when the supply of this nutrient is low.

By the prevention of luxury consumption of K, thus conserving the K-supply.

By exerting an essential or beneficial effect regardless of the K-supply.

By overcoming any unbalance of the Ca-K ratio in the soil and in the plant.

By increasing the absorption of other nutrient elements.

Work with Ranger alfalfa showed that plants that received large amounts of K absorbed only slight amounts of sodium. (21)

A survey of investigations made in Europe and America regarding the effect of sodium on plant growth and the possibility of it serving as an essential plant nutrient brought out the following conclusions :

Sodium apparently has no special function in crops which are benefitted only in a deficiency of K. It evidently assists with the functions of K. (7)

Bear and Wallace (4) have found that lack of Mg tends to become a limiting factor in alfalfa production when the content falls below 0.24 percent of the dry weight.

The most significant single factor influencing the Mg uptake of alfalfa plants is the quantity of K available for their use. (4) As the K supply decreases with repeated harvests of a crop like alfalfa, the Mg content of the plant increases, even when it is

growing on a soil very deficient in Mg.

Lack of correlation between critical Ca:K ratios in the plant and plant yields may occur when sufficient Mg is available in the soil to serve as a partial substitute for K if the latter element is present in very low amounts.

One of the functions ascribed to magnesium in plant nutrition is that of a carrier of the phosphorus used by the plant.

Truog, et. al. (18) investigated the relation of the supply of available magnesium to the phosphorus content of peas by means of field and nutrient culture tests in which the supplies of available magnesium and phosphorus were varied.

Chemical analysis of the pea seeds revealed an appreciable and consistent increase in the phosphorus content with increasing supplies of available magnesium. This supports the theory that magnesium acts as a carrier of phosphorus.

MATERIALS AND METHODS

Chemical Treatments

Fertilizer trials were established on alfalfa fields at Manhattan and Kingman in the spring of 1952. The treatments employed are listed in Table 1.

In the spring of 1951, fertilizer trials were established at the Thayer Experiment Field to investigate the effects of various levels of phosphorus and potassium upon the growth and chemical composition of legumes and legume-grass mixtures.

Table 1. Fertilizer treatments employed 1951-1952.

At Manhattan and Kingman	At Thayer
1. No treatment.	1. Low PK (No fertilizer added.)
2. P (200# P_2O_5/A)	2. Med PK (270#/A-P205, 400#/A K_2O)
3. K (200# K_2O/A)	3. High PK (540#/A-P205, 800#/A K_2O)
4. K as Sul-Po-Mag (200# K_2O/A)	4. Med P (270#/A P_2O_5)
5. PK	5. Med K (400#/A K_2O)
6. PK (Sul-Po-Mag)	6. Common PK (50#/A P_2O_5-60#/A K_2O)
7. PK + B (50# Borax/A)	
8. PK (Sul-Po-Mag) + B	
9. K + B	
10. K (Sul-Po-Mag) + B	

These trials were only partially successful because of difficulties arising from excessive moisture in 1951 and excessive drought in 1952.

The P_2O_5 was supplied by using superphosphate (0-42-0) and the K_2O was supplied by using Muriate of Potash (0-0-60). Borax was employed as a source of boron. "Sul-Po-Mag" which is a double sulfate salt, ($K_2SO_4 . 2MgSO_4$) was compared with Muriate of potash as a source of K_2O. "Sul-Po-Mag" is the trade name for langbeinite ore and supplies about 21 percent K_2O and 18.5 percent MgO.

Harvesting of Plots

The plots were harvested by mowing at one-tenth to one-half bloom stage. The swath was weighed on a portable scale in the field. Samples for chemical analysis were taken simultaneously and dried in an oven.

After drying the entire plants (leaves and stems) were ground and stored. Just before digestion, the samples were dried in an oven at 100° Centigrade for twenty-four hours.

After drying in the oven, one gram samples for digestion and

chemical analysis were weighed out. They were analyzed for percentage composition of protein, phosphorus, potassium, sodium, calcium, and magnesium by standard laboratory procedures.

Chemical Properties of Soils

Soil tests were made on the Manhattan and Kingman soils. The following chemical properties were ascertained.

Table 2. Chemical properties of soils used in test.

			Pounds Per Acre		
Location	pH	Organic Matter	Lime Requirements	Available Phosphorus	Exchangeable Potassium
Manhattan	5.6	1.55	5,000	49	550
Kingman	5.7	1.30	4,000	31	299

Chemical Analyses of Plant Material

Because of rapidity and ease of digestion and the small amounts of reagents used, wet digestion in a mixture of $HClO_4$, HNO_3, and H_2SO_4 was used. This procedure is described by Piper. (12) The digest was diluted with .4N HCl to a volume of 100 ml and aliquots were taken to determine Na, K, Ca, and Mg, by use of the Beckman spectrophotometer with flame attachment. Phosphorus was determined colorimetrically with the Evelyn photoelectric colorimeter. The concentration of the elements were determined by reference to the proper standardization curves. The protein content of the plant material was determined by the Kjeldahl-Gunning process. (2)

DISCUSSION AND ANALYSES OF RESULTS

Yield Data

No statistical analyses were performed on the yield data. The tables are included to show mainly the difference in yield of successive cuttings and to show what influence soil treatments had on the yield.

Manhattan alfalfa showed the greatest increase in yield from the PK and PK(Sul-Po-Mag) treatments. These treatments also produced close to the highest uptake of phosphorus in the plants, over the no-treatment level. Potassium uptake, however, did not differ significantly from the no-treatment level. With phosphorus alone there was a large increase in yield while potassium alone produced a slight decrease in yield. A reason offered for this is that there probably was poverty adjustment by the plants where phosphorus was concerned. That is, increasing yields were obtained in proportion as the limiting factor (phosphorus) was applied.

The plants showed luxury consumption where potassium was concerned. That is, an excessive accumulation of potassium occurred beyond the plant's need, but without reduction in yield. Table 6 shows the high content of potassium in the plants.

The phosphorus treatment alone produced the highest yield of alfalfa at Kingman. Potassium alone reduced the yield below the no-treatment level. The reasons offered for Manhattan alfalfa can be applied here.

Thayer alfalfa showed the greatest yield from the medium level of phosphorus applied alone.

With both alfalfa-bromegrass mixture and with red clover, the common level of PK gave the greatest yield.

Under the drought conditions which prevailed, there was no indication that the high level of phosphorus and potassium treatments was desirable. In general, this treatment had no tendency to increase the yields and in the case of alfalfa it had a tendency to depress the yield.

Apparently magnesium and sulphur supplied by "Sul-Po-Mag" and boron supplied by Borax were not effective in increasing yields at Manhattan and Kingman.

Table 3. Effect of various fertilizer applications on yield of alfalfa - 1952

Treatment	Manhattan				Kingman		
	1st cutting lbs/A	2nd cutting lbs/A	3rd cutting lbs/A	total lbs/A	1st cutting lbs/A	2nd cutting lbs/A	total lbs/A
1. No Treatment	1860	2225	912	4997	2314	1464	3778
2. P	1848	2442	1077	5367	2559	1656	4215
3. K	1777	2280	902	4959	2005	1234	3239
4. K (Sul-Po-Mag)	1863	2329	1005	5197	2109	1288	3397
5. PK	2061	2490	1191	5742	2434	1441	3875
6. PK(Sul-Po-Mag)	2113	2528	1103	5744	2279	1370	3649
7. PK + B	1937	2465	1096	5498	2220	1346	3566
8. PK (Sul-Po-Mag)	1973	2509	1194	5676	2561	1430	3991
9. K + B	1905	2313	895	5113	1846	1189	3035
10. K (Sul-Po-Mag) + B	1834	2318	970	5122	1909	1281	3190

Table 4. Effect of various levels and combinations of fertilizers upon the yield of hay at Thayer, Kansas - 1952

Treatment Description	1st Cutting lbs/A	2nd Cutting lbs/A	3rd Cutting lbs/A	Total Yield lbs/A
		Alfalfa		
Low PK	1245	1002	641	3190
Medium PK	1521	1214	811	3546
High PK	1085	857	714	2656
Medium P	1795	1181	762	3738
Medium K	1341	1085	678	3104
Common PK	1472	1289	752	3513
		Alfalfa-Bromegrass Mixture		
Low PK	860	790	333	1983
Medium PK	1145	908	382	2435
High PK	862	855	382	2099
Medium P	1033	849	460	1649
Medium K	615	719	315	1649
Common PK	1265	903	430	2598
		Red Clover		
Low PK	1114	349	---	1463
Medium PK	1113	373	---	1486
High PK	1012	433	---	1445
Medium P	1443	333	---	1776
Medium K	1257	389	---	1636
Common PK	1489	425	---	1914

Analyses of Plant Material

Consideration first will be given to the chemical composition of each cutting from each location. Values are means of duplicate samples.

Each cutting was analyzed statistically to determine if there was any significance due to effects of treatments as compared to no treatments.

The experiment involved a randomized complete block design which was used because the variation between replications was not expected to be large. Grouping into blocks provided one-dimensional control of error.

The following tables contain the chemical composition for each element, for each cutting. Analyses of variance are not shown but the differences required for significance between treatments are indicated in each table where significant differences existed.

Manhattan Alfalfa. It can be noted by looking at Table 5 that the ten soil treatments had little influence on the protein content of the plants. There was no significant difference between treatments. There was a highly significant difference between cuttings. The second cutting was slightly lower in content of protein than the first or third cutting. Content of phosphorus was much lower in the second butting than in the first or third cuttings. Plants grown in mid-summer contain relatively high amounts of fiber, which dilute mineral, vitamin and protein portions.

Table 5. Effect of various fertilizer treatments on the protein content of alfalfa - 1952.
Manhattan, Kansas

	Protein Content (percent)																	
	First Cutting						Second Cutting						Third Cutting					
	Replication						Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	19.5	21.0	21.4	21.3	19.8	20.6	19.2	18.2	20.1	20.4	20.5	19.7	19.8	20.5	20.7	19.9	21.2	20.4
2. P	19.3	17.9	17.5	21.1	20.6	19.3	20.3	20.6	19.2	19.2	20.7	20.0	20.8	19.8	20.6	19.9	21.4	20.5
3. K	18.9	20.0	23.3	19.3	21.2	20.5	18.1	18.8	19.0	19.9	19.5	19.1	20.6	20.8	20.3	19.6	21.5	20.5
4. K(Sul-Po-Mag)	18.0	21.7	20.4	20.7	22.0	20.6	19.6	18.8	18.2	18.9	19.7	19.0	20.1	20.1	21.6	20.4	20.8	20.6
5. PK	21.9	20.1	22.3	20.2	20.7	21.0	19.6	19.4	18.7	19.7	20.6	19.6	20.8	20.2	20.2	20.4	20.0	20.3
6. PK(Sul-Po-Mag)	19.6	20.6	21.0	21.8	20.9	20.8	19.3	19.8	19.8	18.4	19.2	19.3	20.2	20.1	20.6	20.8	20.0	20.3
7. PK+B	21.5	18.7	22.1	20.8	22.1	21.0	19.7	18.9	18.7	20.0	20.6	19.6	20.8	20.3	20.1	20.4	20.6	20.4
8. PK(Sul-Po-Mag)+B	20.5	21.3	21.4	19.9	21.8	21.0	19.5	20.7	19.9	19.7	20.8	20.1	20.7	19.9	20.1	21.3	20.1	20.4
9. K + B	20.2	20.4	20.9	21.2	18.6	20.3	18.5	17.2	20.4	19.8	19.9	19.2	18.2	19.6	19.1	21.0	19.9	19.5
10. K(Sul-Po-Mag)+B	19.1	19.6	18.2	20.6	21.5	19.8	20.4	17.8	19.1	18.4	19.6	19.1	20.4	19.8	20.1	19.8	21.2	20.3
LSD (.05)						N S						N S						N S
LSD (.01)						N S						N S						N S

Table 6. Effect of various fertilizer treatments on the potassium content of alfalfa. 1952
Manhattan, Kansas

	Potassium Content (percent)																	
	First Cutting						Second Cutting						Third Cutting					
	Replication						Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	2.09	2.75	2.59	2.62	2.69	2.55	2.15	2.25	1.94	2.14	2.05	2.10	2.26	1.94	1.81	1.88	1.94	1.97
2. P	2.12	3.03	2.50	2.75	2.84	2.69	2.14	2.11	2.02	2.06	2.14	2.10	2.23	2.34	2.12	2.12	2.02	2.17
3. K	2.56	2.53	2.81	2.50	2.53	2.59	2.29	2.25	2.34	1.96	2.06	2.18	1.97	2.03	2.00	1.94	1.88	1.96
4. K(Sul-Po-Mag)	2.19	2.38	2.66	2.72	2.45	2.48	2.05	2.78	2.59	2.38	2.09	2.38	2.28	2.19	1.88	2.10	1.98	2.08
5. PK	2.19	2.47	2.50	2.81	2.75	2.54	2.18	2.35	2.28	2.19	2.18	2.23	2.39	2.44	1.78	2.10	2.28	2.20
6. PK(Sul-Po-Mag)	2.59	3.06	2.62	2.66	2.62	2.71	2.14	2.65	2.09	2.18	2.75	2.36	2.38	2.39	1.75	2.02	2.38	2.18
7. PK + B	2.31	2.06	2.69	2.79	2.52	2.47	1.95	2.70	2.35	2.29	2.15	2.29	2.09	2.28	2.00	2.19	2.02	2.12
8. PK(Sul-Po-Mag)+B	2.66	2.66	2.65	2.50	2.44	2.60	2.11	2.71	2.30	2.38	2.05	2.31	2.08	2.50	2.00	2.00	2.28	2.17
9. K + B	2.56	2.44	2.01	2.75	2.50	2.45	2.08	2.50	2.04	2.15	2.00	2.15	2.22	2.22	2.15	1.88	1.78	2.05
10. K(Sul-Po-Mag)+B	3.00	2.69	2.36	2.74	2.64	2.68	2.18	1.80	2.15	2.45	2.14	2.14	2.22	2.16	2.15	2.11	1.92	2.11
LSD						N S						N S						N S
LSD						N S						N S						N S

Table 7. Effect of various fertilizer treatments on the phosphorus content of alfalfa - 1952
Manhattan, Kansas

	Phosphorus Content (percent)																	
	First Cutting						Second Cutting						Third Cutting					
	Replication						Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	.23	.22	.27	.27	.24	.25	.15	.15	.13	.14	.15	.14	.24	.24	.14	.19	.17	.20
2. P	.31	.42	.42	.33	.31	.36**	.16	.17	.16	.17	.17	.17**	.26	.28	.22	.22	.22	.24
3. K	.30	.27	.29	.26	.25	.27	.14	.14	.20	.13	.16	.15	.20	.29	.18	.19	.18	.21
4. K(Sul-Po-Mag)	.29	.28	.30	.25	.26	.27	.15	.16	.19	.19	.16	.17**	.24	.22	.18	.23	.20	.21
5. PK	.34	.32	.28	.34	.32	.32**	.18	.17	.19	.16	.19	.18**	.26	.29	.19	.24	.29	.19
6. PK(Sul-Po-Mag)	.41	.36	.31	.32	.32	.34**	.16	.19	.19	.19	.19	.18**	.26	.31	.18	.23	.29	.25
7. PK + B	.30	.38	.32	.32	.30	.32**	.16	.17	.18	.19	.16	.17**	.23	.25	.19	.28	.22	.23
8. PK(Sul-Po-Mag)+B	.39	.28	.30	.36	.30	.32**	.16	.17	.18	.17	.16	.17**	.24	.29	.21	.23	.22	.24
9. K + B	.27	.23	.25	.30	.25	.26	.15	.18	.16	.16	.13	.16**	.23	.22	.20	.19	.19	.20
10. K(Sul-Po-Mag)+B	.34	.26	.26	.26	.26	.28*	.15	.18	.17	.17	.16	.16**	.25	.22	.21	.23	.20	.22
LSD (.05)						.031						.013						N S
LSD (.01)						.041						.017						N S

* Differs from no treatment at 5 percent level.
** Differs from no treatment at 1 percent level.

Table 8. Effect of various fertilizer treatments on the calcium content of alfalfa. Manhattan, Kansas - 1952.

Treatment	Calcium Content (percent) First Cutting Replication I	II	III	IV	V	Ave.	Second Cutting Replication I	II	III	IV	V	Ave.	Third Cutting Replication I	II	III	IV	V	Ave.
1. No Treatment	.58	.67	.81	.72	.70	.70	.87	1.00	.97	.98	1.04	.97	.87	.87	1.12	1.11	1.00	1.00
2. P	.56	.74	.77	.74	.66	.69	.88	.92	.88	.94	.91	.90*	.90	.88	.97	1.12	1.03	.98
3. K	.78	.72	.78	.61	.67	.71	.94	.95	1.12	1.06	.96	1.00	.86	.92	1.03	1.20	1.06	1.01
4. K(Sul-Po-Mag)	.74	.68	.66	.56	.68	.66	.91	.90	.92	.98	1.00	.94	.91	.90	.96	1.11	.98	1.17
5. PK	.68	.73	.64	.65	.66	.67	.90	.87	.98	.88	1.04	.93	.84	.87	1.00	1.03	1.23	.99
6. PK(Sul-Po-Mag)	.74	.72	.58	.61	.54	.64	.87	.99	.86	.96	1.08	.95	.84	.90	1.04	1.04	1.11	.97
7. PK + B	.72	.69	.66	.61	.61	.66	.94	.86	.96	1.02	.98	1.16*	.87	.95	1.01	1.14	1.04	1.00
8. PK(Sul-Po-Mag) +B	.75	.61	.66	.62	.65	.66	.84	.92	.88	.94	.91	.90	.91	.95	.87	1.15	1.10	1.00
9. K + B	.71	.66	.61	.67	.50	.63	1.02	1.17	1.00	.97	.97	1.02*	.84	.91	.98	1.11	1.03	.97
10. K(Sul-Po-Mag)+B	.76	.66	.66	.58	.62	.66	.95	.88	.89	1.00	.94	.93	.86	.87	1.01	1.01	.96	1.14
LSD (.05)							N S					N S						N S
LSD (.01)							N S					N S						N S

Table 9. Effect of various fertilizer treatments on the sodium content of alfalfa. 1952
Manhattan, Kansas

	Sodium Content (percent)																	
	First Cutting						Second Cutting						Third Cutting					
	Replication						Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	.010	.013	.009	.011	.026	.014	.016	.010	.012	.013	.018	.014	.026	.030	.009	.010	.008	.017
2. P	.021	.026	.011	.011	.029	.020	.015	.013	.013	.017	.020	.016	.024	.028	.010	.010	.010	.017
3. K	.016	.016	.012	.008	.025	.015	.013	.018	.016	.010	.010	.013	.023	.020	.010	.009	.009	.018*
4. K(Sul-Po-Mag)	.022	.022	.010	.010	.027	.018	.009	.020	.018	.010	.011	.014	.025	.025	.011	.011	.008	.016*
5. PK	.014	.018	.012	.010	.027	.016	.016	.019	.011	.010	.011	.012	.025	.024	.013	.013	.015	.018*
6. PK(Sul-Po-Mag)	.017	.020	.012	.010	.040	.020	.019	.014	.011	.012	.011	.013	.028	.028	.010	.012	.014	.018*
7. PK + B	.016	.028	.012	.010	.033	.020	.014	.016	.014	.011	.020	.015	.027	.026	.009	.011	.010	.017
8. PK(Sul-Po-Mag)+B	.022	.022	.013	.010	.030	.020	.016	.013	.010	.016	.014	.014	.026	.031	.008	.014	.010	.018*
9. K + B	.014	.016	.009	.010	.035	.017	.015	.013	.010	.013	.013	.013	.026	.021	.010	.012	.008	.015*
10. K(Sul-Po-Mag)+B	.018	.019	.011	.011	.029	.018	.013	.015	.012	.010	.023	.015	.028	.027	.010	.015	.010	.018*
LSD (.05)						N S						N S						.011
LSD (.01)						N S						N S						N S

Table 10. Effect of various fertilizer treatments on the magnesium content of alfalfa. 1952. Manhattan, Kansas

Treatment	Magnesium Content (percent)																	
	First Cutting						Second Cutting						Third Cutting					
	Replication						Replication						Replication					
	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	.52	.41	.53	.50	.58	.50	.50	.64	.54	.50	.36	.51	.56	.54	.58	.52	.59	.56
2. P	.52	.56	.56	.54	.59	.55	.50	.64	.46	.44	.57	.52	.50	.56	.56	.53	.62	.55
3. K	.52	.52	.53	.56	.56	.54	.46	.78	.48	.44	.39	.51	.54	.58	.53	.53	.53	.54
4. K(Sul-Po-Mag)	.54	.54	.53	.53	.50	.53	.41	.68	.42	.50	.46	.50	.46	.50	.58	.59	.56	.57
5. PK	.50	.62	.48	.53	.50	.53	.48	.44	.53	.48	.53	.49	.56	.56	.50	.54	.59	.55
6. PK(Sul-Po-Mag)	.54	.65	.48	.52	.56	.55	.43	.36	.39	.53	.53	.45	.54	.56	.50	.56	.65	.56
7. PK + B	.59	.53	.52	.52	.53	.54	.39	.32	.42	.57	.57	.46	.53	.60	.53	.65	.56	.58
8. PK(Sul-Po-Mag)+B	.53	.53	.52	.64	.58	.56	.57	.50	.42	.42	.53	.49	.56	.62	.54	.53	.59	.57
9. K + B	.50	.54	.50	.56	.56	.53	.60	.46	.42	.44	.52	.49	.59	.60	.52	.50	.50	.56
10. K(Sul-Po-Mag)+B	.53	.50	.52	.53	.59	.53	.64	.58	.55	.42	.47	.53	.59	.59	.50	.68	.59	.59
LSD (.05)						N S						N S						N S
LSD (.01)						N S						N S						N S

Apparently sufficient K existed in the plant tissue produced on untreated soil at Manhattan. Addition of K in fertilizer did not materially increase the percentage of this element in the plant tissue.

Statistical analysis of the plant material showed no significant difference between treatments for any cutting. There was a highly significant difference between cuttings. The first cutting contained the highest percent and the third cutting the lowest.

This indicates that each successive cutting was exhausting the supply of available K in the soil and the plants were absorbing much larger quantities of K than are necessary for maximum growth. (4)

Apparently the plant tissues did not contain enough phosphorus to meet the critical nutrient level of .27 percent. (4) According to Morrison average alfalfa hay contains .25 percent phosphorus. (10)

Addition of phosphatic fertilizer alone resulted in a marked increase in content of phosphorus in the plant.

Statistically, there was a significant difference between treatments in both the first and second cuttings. There was no significant difference between treatments of the third cutting. The second cutting is lower in phosphorus content than the first and third cutting. A reason for this has been offered previously. There was a highly significant difference between cuttings.

According to Morrison, alfalfa hay contains 1.47 percent calcium. (10) The generally low content of calcium in the plant material and high content of potassium and magnesium might indicate

that these latter elements retarded the uptake of calcium by the plants. Also since the Manhattan soil is on the acid side (pH 5.6) hydrogen ions could be antagonistic toward Ca ion uptake.

It can be noted, however, from the tables that as the percentage of potassium in each successive cutting became smaller the percentage of calcium became larger.

There was no significance between treatments of the first cutting and third cutting. There was, however, significance between treatments of the second cutting (5 percent level). There was a difference between cuttings also.

Magnesium content of alfalfa at Manhattan was not appreciably affected by soil treatment. The Mg content of the plant material was about twice the critical lower limit established at New Jersey. (4)

Statistical analyses indicated that there was no difference between treatments for any cutting or between cuttings. In other words, the soil treatments had no effect upon the magnesium content of the plant.

The high content of magnesium was probably exerting a retarding effect upon the uptake of calcium by the plants.

Kingman Alfalfa. Because of weather conditions, the growth of alfalfa was not great at Kingman so only two cuttings were taken.

There was no significance in the variation of the protein content between treatments of either cutting. There was a difference between cuttings, the second cutting being higher in protein content.

Apparently sufficient K existed in the plant tissue produced on untreated soil at Kingman. Addition of K did not appreciably increase the percentage of this element in the plant tissue.

There was a significance (5 percent level) between treatments of the first cutting but not of the second cutting. There was a difference between cuttings, the first cutting being much higher than the second cutting.

Table 11. Effect of various fertilizer treatments on the protein content of alfalfa. 1952
Kingman, Kansas

	Protein Content (percent)											
	First Cutting						Second Cutting					
	Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	20.1	21.3	18.4	18.5	15.7	18.8	19.6	20.4	21.0	21.2	19.1	20.3
2. P	17.5	15.4	19.9	18.7	15.7	17.4	19.4	20.9	21.9	23.0	20.3	21.1
3. K	19.9	17.0	18.5	18.5	17.9	18.4	21.0	20.9	19.9	20.8	21.4	20.1
4. K(Sul-Po-Mag)	18.8	18.2	19.6	18.4	17.9	18.6	24.5	19.2	20.7	22.8	20.5	21.6
5. PK	22.0	19.6	18.7	18.4	17.3	19.2	19.8	19.4	20.7	22.4	23.1	21.1
6. PK(Sul-Po-Mag)	20.5	19.6	18.2	17.8	17.8	18.8	20.7	20.5	21.1	22.8	22.4	21.5
7. PK + B	21.1	19.6	18.9	17.2	19.4	19.2	23.2	18.8	21.3	23.5	20.2	21.4
8. PK(Sul-Po-Mag)+B	18.2	21.3	19.0	18.8	[illegible]	19.1	22.8	19.7	21.2	23.3	21.7	21.7
9. K + B	20.1	18.5	17.8	20.5	19.0	19.2	20.6	21.2	20.3	20.4	22.1	20.9
10. K(Sul-Po-Mag)+B	18.8	18.5	18.0	19.0	17.1	18.3	22.9	21.2	21.8	21.8	21.1	21.7
*LSD (.05)						N S						N S
**LSD (.01)						N S						N S

* Differs from no treatment at 5 percent level.
** Differs from no treatment at 1 percent level.

Table 12. Effect of various fertilizer treatments on the potassium content of alfalfa. 1952
Kingman, Kansas

	Potassium Content (percent)											
	First Cutting						Second Cutting					
	Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	2.60	2.38	2.65	2.50	3.38	2.70	2.60	2.10	2.35	2.19	1.69	2.04
2. P	2.40	2.81	2.78	2.81	3.50	2.96*	2.40	2.25	2.49	2.10	1.81	2.14
3. K	2.31	2.62	2.72	2.44	2.50	2.52*	2.31	2.51	2.44	2.42	1.91	2.35
4. K(Sul-Po-Mag)	2.55	2.65	2.56	2.35	2.94	2.61	2.55	2.24	2.51	2.52	1.85	2.30
5. PK	2.50	2.81	2.72	2.95	2.69	2.73	2.50	2.30	2.46	1.97	2.39	2.27
6. PK(Sul-Po-Mag)	2.65	2.65	3.06	3.10	2.68	2.87	2.65	2.38	2.55	2.22	2.18	2.34
7. PK + B	2.32	2.82	2.69	2.80	2.98	2.72	2.32	2.34	2.37	2.42	1.76	2.21
8. PK(Sul-Po-Mag)+B	2.75	2.84	3.00	3.02	3.10	2.94*	2.75	2.56	2.44	2.40	2.09	2.40
9. K + B	2.25	2.60	2.90	2.35	2.52	2.52*	2.25	2.62	2.35	1.99	2.24	2.39
10. K(Sul-Po-Mag)+B	2.40	2.50	2.75	2.62	2.85	2.62	2.40	2.71	2.34	2.10	2.00	2.34
LSD (.05)				.19								N S
LSD (.01)				N S								N S

Table 13. Effect of various fertilizer treatments on the phosphorus content of alfalfa. 1952
Kingman, Kansas

	Phosphorus Content (percent)											
	First Cutting						Second Cutting					
	Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	.20	.29	.27	.26	.28	.26	.18	.25	.29	.29	.22	.25
2. P	.32	.36	.35	.35	.52	.35**	.31	.33	.33	.30	.25	.30**
3. K	.22	.33	.20	.20	.24	.24	.26	.30	.23	.27	.20	.25
4. K(Sul-Po-Mag)	.22	.24	.20	.22	.30	.24	.29	.24	.27	.32	.18	.26
5. PK	.28	.37	.32	.34	.32	.33**	.29	.30	.34	.28	.31	.30**
6. PK(Sul-Po-Mag)	.32	.32	.32	.37	.32	.33**	.32	.32	.33	.32	.28	.31**
7. PK + B	.31	.38	.30	.33	.34	.33**	.30	.28	.33	.30	.22	.20**
8. PK(Sul-Po-Mag)+B	.31	.37	.31	.29	.37	.33**	.35	.31	.33	.30	.26	.31**
9. K + B	.22	.24	.25	.19	.25	.23	.26	.26	.28	.21	.24	.25
10. K(Sul-Po-Mag)+B	.19	.24	.22	.27	.21	.22	.26	.26	.25	.27	.21	.24
LSD (.05)						.026						.026
LSD (.01)						.034						.034

Table 14. Effect of various fertilizer treatments on the calcium content of alfalfa. 1952
Kingman, Kansas

	Calcium Content (percent)											
	First Cutting						Second Cutting					
	Replication						Replication					
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	.87	.92	.92	.76	.74	.84	.84	.76	.76	.64	.84	.77
2. P	.76	.91	1.02	.82	.78	.86	.63	.76	.66	.62	.89	.71
3. K	.95	.76	.84	.79	.95	.86	.65	.66	.69	.68	.69	.68
4. K(Sul-Po-Mag)	.76	.84	.79	.81	.89	.82	.64	.68	.70	.64	.88	.71
5. PK	.82	.92	.80	.81	.74	.82	.62	.76	.72	.65	.66	.68
6. PK(Sul-Po-Mag)	.95	.83	.75	.74	.88	.83	.63	.71	.70	.66	.70	.68
7. PK + B	.96	.98	.80	.95	.90	.92	.72	.64	.72	.62	.72	.69
8. PK(Sul-Po-Mag)+B	.79	.96	.72	.98	.86	.86	.69	.73	.66	.61	.78	.70
9. K + B	.96	.93	.89	.79	1.03	.92	.78	.76	.64	.70	.64	.71
10. K(Sul-Po-Mag)+B	.74	.92	.79	.81	.72	.80	.59	.70	.67	.63	.74	.66
LSD (.05)						N S						N S
LSD (.01)						N S						N S

Table 15. Effect of various fertilizer treatments on the sodium content of alfalfa. 1952
Kingman, Kansas

Treatment	Sodium Content (percent) First Cutting Replication I	II	III	IV	V	Ave.	Second Cutting Replication I	II	III	IV	V	Ave.
1. No Treatment	.016	.021	.018	.023	.022	.020	.021	.019	.014	.020	.021	.019
2. P	.027	.021	.021	.030	.030	.026	.017	.024	.016	.022	.020	.020
3. K	.017	.027	.018	.018	.016	.019	.019	.018	.019	.016	.025	.020
4. K(Sul-Po-Mag)	.018	.016	.016	.020	.023	.019	.018	.018	.018	.020	.023	.019
5. PK	.022	.021	.020	.022	.018	.021	.018	.031	.018	.017	.015	.020
6. PK(Sul-Po-Mag)	.024	.023	.023	.030	.016	.023	.018	.017	.020	.022	.018	.019
7. PK + B	.026	.023	.022	.024	.016	.022	.023	.024	.018	.019	.016	.024
8. PK(Sul-Po-Mag)+B	.020	.029	.021	.022	.018	.022	.021	.021	.018	.019	.016	.019
9. K + B	.021	.023	.033	.014	.014	.021	.019	.021	.014	.019	.013	.017
10. K(Sul-Po-Mag)+B	.018	.020	.017	.022	.015	.018	.016	.020	.016	.019	.014	.017
LSD (.05)						N S						N S
LSD (.01)						N S						N S

Table 16. Effect of various fertilizer treatments on the magnesium content of alfalfa. 1952
Kingman, Kansas

	Magnesium Content (percent)											
	First Cutting						Second Cutting					
	Replication											
Treatment	I	II	III	IV	V	Ave.	I	II	III	IV	V	Ave.
1. No Treatment	.56	.62	.45	.72	.55	.58	.46	.60	.48	.46	.62	.52
2. P	.50	.59	.66	.75	.55	.61	.42	.50	.50	.50	.62	.51
3. K	.65	.50	.50	.75	.58	.60	.50	.52	.38	.53	.53	.49
4. K(Sul-Po-Mag)	.59	.56	.45	.77	.58	.59	.46	.60	.39	.60	.57	.53
5. PK	.65	.56	.59	1.08	.52	.68*	.60	.60	.48	.48	.50	.53
6. PK(Sul-Po-Mag)	.68	.66	.66	1.05	.60	.75*	.70	.59	.53	.48	.50	.56
7. PK + B	.56	.59	.41	.96	.54	.61	.40	.50	.55	.57	.44	.49
8. PK(Sul-Po-Mag)+B	.56	.56	.59	.77	.54	.60	.60	.40	.41	.58	.44	.49
9. K + B	.59	.56	.59	1.05	.55	.67*	.42	.50	.44	.52	.42	.46
10. K(Sul-Po-Mag)+B	.53	.56	.54	.88	.49	.66*	.60	.52	.48	.60	.48	.54
LSD (.05)						.080						N S
LSD (.01)						N S						N S

The plant tissues taken from unfertilized Kingman soil were low enough in content of phosphorus so that they appeared to be slightly below the critical nutrient level for this element. It was not so low as Manhattan at the time of the second cutting.

Addition of phosphatic fertilizer alone resulted in a marked increase in content of phosphorus in the plant.

There was a significant difference between the no treatment and the treatments of both cuttings. There was no significant difference between cuttings.

There was a generally low content of calcium in the Kingman plant material as was the case in the Manhattan plant material.

There was no significant difference between treatments of the first or second cutting. There was a difference between cuttings, the first cutting being higher in calcium content.

There was no significant difference between treatments of either cutting and no difference between cuttings when the sodium content was analyzed statistically.

Magnesium content of alfalfa produced at Kingman showed a significant variation between treatments of first cutting but no significance between treatments of second cutting. There was no difference between cuttings.

The magnesium content was about twice the critical lower limit established at New Jersey.

<u>Thayer Alfalfa and Alfalfa-Bromegrass Mixture</u>. Since this experiment was conducted to determine the influence of soil amendments upon the chemical composition of legumes and legume-grass mixtures, the chemical composition from an animal nutrition

standpoint was kept in mind.

Since legume-grass mixtures were fed as hay to cattle and used as pasture, the alfalfa-bromegrass mixture was analyzed to find out just what its chemical composition would be.

Statistical analysis showed that there was no significance between treatments when protein was considered but significance between cuttings (5 percent level) for alfalfa and alfalfa-brome mixture.

Thayer is in southeast Kansas and on some soils in southeast Kansas, yield data indicated that there was a need for potassium fertilizer in addition to phosphorus fertilizer for maximum alfalfa production (11).

Tremendous amounts of fertilizer were used on the Thayer soil but it is of interest to note that none of the treatments applied at Thayer on alfalfa, alfalfa-brome mixture, and red clover brought the content of K in the plants up to the level of K in alfalfa grown at Manhattan where no treatment was applied.

There was no significance between treatments, first cutting of Thayer alfalfa. There was a significant difference between treatments, second cutting however.

Analysis of potassium data for significance showed that there was a difference between treatments, first cutting. (5 percent level). There was no significance between treatments, second cutting, but significance between cuttings (5 percent level).

Large amounts of phosphatic fertilizer were used on the Thayer soil. However, phosphorus in the plants did not materially increase over the no-treatment level in alfalfa nor the alfalfa-

brome mixture. Lack of moisture could have been one cause of this. Phosphorus fixing capacity of this soil may also be very high and as a consequence much of the soluble phosphorus added as superphosphate in 1951 may have been rendered quite insoluble.

Analyses of the phosphorus data indicated no significance in the variation between treatments of the second cutting. There was a significance between cuttings (5 percent level for alfalfa - 5 percent and 1 percent level for alfalfa-bromegrass mixture).

Sodium data were analyzed and found to have no significant variation between treatments or cuttings for either alfalfa or alfalfa-bromegrass mixture. It is interesting to note that the sodium percentage in Thayer plant tissue was higher and potassium was lower than plant tissue from Manhattan or Kingman. When there is an excess of K in the plant tissue the Na content is low.

Table 17. Effect of various fertilizer treatments on the protein content of alfalfa and alfalfa-bromegrass mixture, Thayer, Kansas, 1952.

Treatment	Protein Content (percent)											
	Alfalfa						Alfalfa-Brome Mixture					
	First Cutting			Second Cutting			First Cutting			Second Cutting		
	I	II	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.
Low Pk	21.9	21.0	21.5	22.6	23.0	22.8	21.7	20.9	21.4	22.1	21.0	21.6
Med PK	19.7	22.8	21.3	22.5	22.8	22.6	22.0	19.6	20.8	21.8	20.4	21.1
High PK	22.6	21.7	22.1	21.9	22.8	22.4	20.6	18.4	19.5	21.8	19.7	20.8
Med P	21.9	20.9	21.4	22.3	22.2	22.2	22.5	19.9	21.2	20.4	22.0	21.2
Med K	20.6	20.4	20.5	23.1	21.2	22.2	22.0	19.8	20.9	22.7	21.7	22.2
Common PK	21.0	20.0	20.6	21.8	21.5	21.7	18.4	21.7	20.1	20.0	20.0	21.2
LSD (.05)			N S			N S			N S			N S
LSD (.01)			N S			N S			N S			N S

Table 18. Effect of various fertilizer treatments on the potassium content of alfalfa and alfalfa-bromegrass mixture, Thayer, Kansas - 1952.

	Potassium Content (Percent)											
	Alfalfa						Alfalfa-brome Mixture					
	First Cutting			Second Cutting			First Cutting			Second Cutting		
Treatments	I	II	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.
Low PK	1.31	1.39	1.35	1.31	1.28	1.30	1.24	1.24	1.24	1.29	1.18	1.23
Med PK	1.00	1.69	1.34	1.64	1.56	1.60**	1.76	1.69	1.73*	1.47	1.49	1.48
High PK	1.97	1.88	1.92	1.81	1.78	1.80**	1.89	2.01	1.95*	1.52	1.45	1.48
Med P	1.25	1.25	1.25	1.26	1.31	1.29	1.33	1.57	1.40	1.52	1.27	1.39
Med K	1.18	1.72	1.45	1.56	1.78	1.67**	1.93	1.66	1.80*	1.60	1.31	1.45
Common PK	1.41	1.38	1.39	1.53	1.41	1.49*	1.75	1.45	1.60	1.27	1.17	1.22
LSD (.05)			N S			.13			.20			N S
LSD (.01)			N S			.20			N S			N S

Table 19. Effect of various fertilizer treatments on the phosphorus content of alfalfa and alfalfa-bromegrass mixture, Thayer, Kansas - 1952.

	Phosphorus Content (Percent)											
	Alfalfa						Alfalfa-Brome Mixture					
	First Cutting			Second Cutting			First Cutting			Second Cutting		
Treatment	I	II	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.
Low PK	.25	.23	.24	.22	.22	.22	.24	.22	.23	.18	.20	.19
Med PK	.23	.27	.25	.24	.22	.23	.35	.24	.30	.19	.21	.20
High PK	.26	.25	.25	.22	.21	.22	.30	.21	.26	.21	.20	.20
Med P	.25	.24	.25	.22	.22	.22	.26	.27	.27	.21	.21	.21
Med K	.19	.21	.20	.19	.21	.20	.21	.23	.22	.16	.19	.18
Common PK	.21	.21	.21	.22	.20	.21	.23	.25	.24	.20	.20	.20
LSD (.05)			N S			N S			N S			N S
LSD (.01)			N S			N S			N S			N S

Table 20. Effect of various fertilizer treatments on the sodium content of alfalfa and alfalfa-bromegrass mixture, Thayer, Kansas - 1952.

	Sodium Content (percent)											
	Alfalfa						Alfalfa-brome Mixture					
	First Cutting			Second Cutting			First Cutting			Second Cutting		
Treatment	I	II	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.
Low PK	.140	.100	.120	.090	.060	.080	.070	.07	.070	.070	.040	.060
Med PK	.080	.080	.080	.040	.050	.040	.070	.02	.050	.060	.030	.040
High PK	.090	.050	.090	.060	.040	.050	.020	.02	.020	.040	.040	.040
Med P	.120	.150	.140	.090	.040	.060	.070	.07	.070	.050	.050	.050
Med K	.060	.040	.050	.060	.020	.040	.060	.03	.040	.060	.040	.060
Common PK	.110	.080	.090	.050	.040	.040	.100	.05	.070	.040	.040	.040
LSD (.05)			N S			N S			N S			N S
LSD (.01)			N S			N S			N S			N S

Table 21. Effect of various fertilizer treatments on the calcium content of alfalfa and alfalfa-bromegrass mixture, Thayer, Kansas - 1952

	Calcium Content (percent)											
	Alfalfa						Alfalfa-brome Mixture					
	First Cutting			Second Cutting			First Cutting			Second Cutting		
Treatment	I	II	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.
Low PK	.76	.82	.79	.66	.61	.64	.65	.81	.73	.59	.76	.68
Med PK	.72	.73	.72	.53	.64	.58	.53	.70	.62	.56	.67	.62
High PK	.59	.75	.67	.67	.56	.62	.56	.65	.60	.67	.60	.64
Med P	.72	.76	.74	.66	.64	.65	.70	.72	.71	.59	.64	.62
Med K	.61	.86	.73	.51	.56	.54	.48	.68	.58	.45	.68	.56
Common PK	.79	.95	.87	.61	.56	.58	.64	.54	.59	.75	.72	.73
LSD (.05)			N S			N S			N S			N S
LSD (.01)			N S			N S			N S			N S

Table 22. Effect of various fertilizer treatments on the protein content of red clover. Thayer, Kansas - 1952.

Treatment	Protein Content (percent)									
	First Cutting					Second Cutting				
	V-Series		W-Series			V-Series		W-Series		
	I	II	I	II	Ave.	I	II	I	II	Ave.
Low PK	22.2	22.3	20.7	20.9	21.5	14.0	13.3	13.3	13.3	13.5
Med PK	20.5	23.0	19.5	21.4	21.1	13.4	13.6	13.3	14.4	13.7
High PK	23.0	22.8	20.8	21.4	22.0	13.8	14.1	14.4	14.5	14.2
Med P	21.3	20.2	21.2	19.0	20.4	13.8	13.8	14.5	13.7	13.9
Med K	20.4	22.0	20.8	21.3	21.1	13.6	14.6	13.6	14.2	14.0
Common PK	20.4	18.9	22.6	20.5	20.6	14.2	13.7	14.9	14.0	14.2
LSD (.05)					N S					N S
LSD (.01)					N S					N S

The large amounts of phosphatic and potash fertilizers added to the Thayer soil resulted in a reduction of the Ca content in the plant to below the no treatment level. The soil at Thayer is already low in K and it seems that K, Na, and Ca are in definite competition with each other in the plant.

There was no significant variation between treatments or cuttings for the alfalfa-bromegrass mixture. There was significance in the variation between cuttings for the alfalfa.

Thayer Red Clover. Red Clover is similar and almost equal to alfalfa in its performance and chemical composition. Statistical analyses of the Thayer Red Clover data revealed about the same things as for Thayer alfalfa.

For protein, there was no significance between the no-treatment level and treatments and also no difference between cuttings.

For potassium, there was no significance between the variation in either treatments or cuttings.

Statistical analyses of the data for phosphorus showed significance between treatments, of the first cutting, but no significance between treatments of the second cutting. There was a significant variation between cuttings.

Statistical interpretation of the sodium data indicated no significance between treatments of either cutting, but significance between cuttings.

Table 23. Effect of various fertilizer treatments on the potassium content of red clover. Thayer, Kansas - 1952.

Treatment	Potassium Content (percent)									
	First Cutting					Second Cutting				
	V-Series		W-Series			V-Series		W-Series		
	I	II	I	II	Avg.	I	II	I	II	Avg.
Low PK	1.40	1.38	1.50	1.62	1.48	1.09	.97	1.03	1.00	1.02
Med PK	2.03	1.78	1.94	1.97	1.93**	1.03	1.14	1.06	1.06	1.07
High PK	2.12	2.12	2.56	2.25	2.27**	1.09	1.06	1.22	1.16	1.13
Med P	1.56	1.44	1.47	1.47	1.48	1.09	1.03	1.10	1.31	1.16
Med K	1.01	1.88	2.53	2.19	2.12**	1.12	1.25	1.22	1.44	1.26
Common PK	1.69	1.53	1.84	1.62	1.67**	1.47	1.16	1.06	1.16	1.21
LSD (.05)					.17					N S
LSD (.01)					.23					N S

Table 24. Effect of various fertilizer treatments on the phosphorus content of red clover. Thayer, Kansas - 1952

	Phosphorus Content (percent)									
	First Cutting					Second Cutting				
	V-Series		W-Series			V-Series		W-Series		
Treatment	I	II	I	II	Ave.	I	II	I	II	Ave.
Low PK	.21	.20	.21	.20	.20	.10	.12	.10	.12	.11
Med PK	.21	.22	.23	.24	.22**	.11	.11	.13	.09	.11
High PK	.25	.23	.27	.27	.26**	.09	.11	.12	.10	.10
Med P	.22	.22	.23	.28	.24**	.11	.10	.12	.11	.11
Med K	.20	.20	.21	.23	.21	.10	.09	.10	.11	.10
Common PK	.23	.21	.21	.24	.22*	.13	.11	.10	.11	.11
LSD (.05)					.015					N S
LSD (.01)					.020					N S

Table 25. Effect of various fertilizer treatments on the sodium content of red clover. Thayer, Kansas - 1952

Treatment	Sodium Content (percent)									
	First Cutting					Second Cutting				
	V-Series		W-Series			V-Series		W-Series		
	I	II	I	II	Ave.	I	II	I	II	Ave.
Low PK	.012	.010	.003	.003	.007	.010	.010	.022	.015	.014
Med PK	.012	.010	.002	.003	.007	.010	.008	.015	.020	.013
High PK	.006	.010	.005	.002	.006	.008	.005	.010	.022	.011
Med P	.007	.008	.003	.002	.005	.010	.008	.015	.024	.014
Med K	.007	.010	.002	.003	.005	.008	.008	.016	.020	.013
Common PK	.004	.007	.002	.003	.004	.010	.010	.016	.022	.015
LSD (.05)					N S					N S
LSD (.01)					N S					N S

Table 26. Effect of various fertilizer treatments on the calcium content of red clover. Thayer, Kansas - 1952.

Treatment	Calcium Content (percent)									
	First Cutting					Second Cutting				
	V-Series		W-Series			V-Series		W-Series		
	I	II	I	II	Ave.	I	II	I	II	Ave.
Low PK	.51	.53	.59	.56	.55	.57	.61	.53	.56	.57
Med PK	.44	.47	.42	.47	.45**	.57	.56	.56	.54	.56
High PK	.40	.47	.50	.44	.45**	.59	.53	.56	.53	.55
Med P	.51	.55	.53	.59	.54	.59	.53	.53	.51	.54
Med K	.45	.45	.45	.47	.46**	.57	.56	.56	.50	.55
Common PK	.56	.53	.48	.49	.52	.56	.53	.50	.51	.52
LSD (.05)					.041					N S
LSD (.01)					.057					N S

For calcium there was significance in the variation between treatments of the first cutting. There was no significance between treatments of the second cutting. There was significance (5 percent level) between cuttings.

It can be readily noticed from the tables that except for calcium all the other elements analyzed for were considerably higher in content in the first cutting than in the second.

A look at the yield data will show that the yield for the second cutting was considerably lower than for the first. There was a poor second growth because of weather conditions.

SUMMARY

Data accumulated in this investigation indicate that the alfalfa grown at Manhattan and Kingman was well above the critical lower level with respect to its content of Mg and K. Calcium content was lower than is normally reported in the literature for alfalfa. Probably the relatively low content of Ca was due to a considerable extent to the rather high concentration of K and Mg. Further experimentation in which limestone or other calcium bearing materials are used might establish more clearly the role of Ca in such soils.

Concentration of phosphorus in alfalfa at Manhattan, was definetely below the critical lower level for this element in each of the cuttings. The phosphorus content at Kingman was not so low as at Manhattan, but it appeared to be somewhat below the critical lower limit. In each case the addition of superphosphate brought about increases in yields and increases in

the phosphorus content of the alfalfa.

Soil at Thayer was naturally unsuited for the production of legumes or legume-grass mixtures because of deficiencies of phosphorus, potassium and lime in the soil. The addition of considerable fertilizer to the soil resulted in some increase in the uptake of K where large amounts of muriate of potash were applied. Increases in the uptake of phosphorus were relatively small even after very large amounts of superphosphate were added. There was definite indication of suppressed Ca uptake as a result of additions of K. More research is necessary at Thayer before final conclusions can be made as to the absolute nutrient needs of these crops and as to the requirements for purposes of satisfactory animal nutrition.

A question as to whether the alfalfa from Manhattan would contain enough calcium to be suitable for feeding can be answered thus for a cow in milk which is being fed good alfalfa, soybean, or cowpea hay (at least 1 lb. daily per 100 lbs. live weight) with corn silage, sorghum silage, corn fodder, sorghum fodder or roots.

For an 1800 lb. cow producing 40 lbs. milk per day, .1040 lb. Ca per day is needed for maintenance, and .0022 lb. is needed for each pound of milk produced, according to Morrison's "Feeds and Feeding." This would be .120 lb. of Ca for the 1800 lb. cow.

If 18 lbs. of the alfalfa grown at Kingman or Manhattan are fed, the cow will receive about .160 lb. of Ca.

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THE INFLUENCE OF SOIL TREATMENTS UPON THE CHEMICAL COMPOSITION OF LEGUMES AND LEGUME-GRASS MIXTURES

by

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ABSTRACT OF THESIS

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Fertilizer trials were established on alfalfa fields at Manhattan and Kingman in the spring of 1952. The purpose of the trials was to investigate the effects of additions to the soil of potassium, phosphorus, sulfur, magnesium, and boron on the growth and chemical composition of alfalfa.

In the spring of 1951, fertilizer trials were established at the Thayer Experiment Field to investigate the effects of various levels of phosphorus and potassium on the growth and chemical composition of legumes and legume grass mixtures.

The plots were harvested by mowing at one-tenth to one-half bloom stage. The swath was weighed on a portable scale in the field. Samples for chemical analysis were taken simultaneously and dried in an oven at 100° Centigrade for twenty-four hours.

After drying in the oven, one gram samples for digestion and chemical analysis were weighed out. They were analyzed for percentage composition of protein, phosphorus, potassium, sodium, calcium, and magnesium by standard laboratory procedures.

Because of rapidity and ease of digestion and the small amounts of reagents used, wet digestion in a mixture of $HClO_4$, HNO_3, and H_2SO_4 was used. The digest was diluted with .4NHCl to a volume of 100 ml. and aliquots were taken to determine Na, K, Ca, and Mg. by use of the Beckman spectrophotometer with flame attachment. Phosphorus was determined colorimetrically with the Evelyn photoelectric colorimeter. The concentration of the elements were determined by reference to the proper standardization curves. The protein content of the plant material was determined by the Kjeldahl-Gunning process.

Each cutting was analyzed atatistically to determine if there was any significance due to effects of treatment as compared to no treatment. The experiment involved a randomized complete block design which was used because variations between replications was not expected to be large. No statistical analyses were performed on the yield data.

The data accumulated in this study indicate that the plant material grown at Manhattan and Kingman is well above the critical level with respect to its content of Mg., and K. Phosphorus appeared to be a limiting factor because marked response in yield and phosphorus content in the plants resulted from addition of phosphatic fertilizer alone.

However, Ca is lower than normal. Further experiments using lime or other calcium bearing materials as soil amendments can probably bring out the effects of the addition of calcium to the soil.

This study also shows that the soil at Thayer is naturally unsuitable for growing alfalfa because it requires considerable fertilizer to raise the content of the potassium, calcium, and phosphorus in the plants grown there to where it could be suitable for feeding livestock.